Reassessing the skill of GCM-simulated precipitation

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1. Introduction

A changing climate is likely to result in changes in global precipitation patterns and the realistic simulation of precipitation remains a major challenge in global climate modelling. The skill of precipitation simulated by General Circulation Models (GCMs) has not been fully assessed as comparison with observations is complicated by two sources of error:

1. Prognostic large-scale variables do not reflect temporal variability in observations, as GCMs do not assimilate any historical data.

2. The parameterisation of precipitation, which is based on the prognostic variables, may not be accurate.

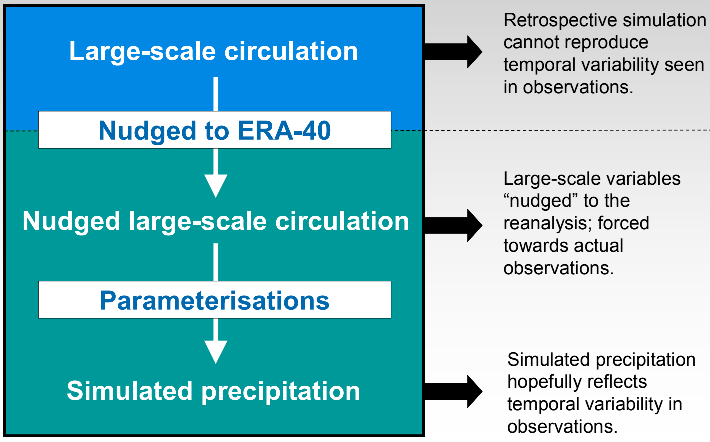
Atmospheric reanalyses have recently been shown to produce reliable precipitation estimates (e.g. Janowiak *et al*., 1998; Bosilovich *et al*., 2008). A reanalysis is able to assimilate a range of observed atmospheric variables within a background forecast model (Bosilovich *et al*., 2008), and as such, it can be considered an 'ideal' GCM in which the large-scale circulation is in good agreement with reality (Widmann and Bretherton, 2000).

Here, we extend this validation of precipitation to the ECHAM5 GCM by ensuring that the large-scale circulation is in good agreement with observations.

2. Approach

ECHAM5 is the fifth generation of the ECHAM GCM and its climate change simulations were included in the IPCC Fourth Assessment Report (AR4) published in 2007. We conduct a retrospective simulation in which temporal variability is well-represented and subsequently produce, for the first time, a spatial quantification of the skill of ECHAM5 precipitation.

The nudging technique, based on Newtonian relaxation, was used to force the ECHAM5 temperature, divergence and vorticity fields to corresponding values from the ECMWF 40 year reanalysis (ERA-40). An outline of the nudging process and subsequent parameterisation of precipitation is shown below.



3. Precipitation validation

A normal (non-nudged) ECHAM5 simulation is unable to represent interannual variability in seasonal mean precipitation (Figure 1a); global simulated/observed correlation coefficients deviate around zero (Nieto *et al*., 2004). In contrast, precipitation from the nudged simulation captures well observed interannual variability in many regions of the world (Figure 1b; due to display limitations, we show DJF only).

Correlation coefficients average 0.53 across the extra-tropical domain (60° - 30°) and are especially strong and positive over large parts of the northern hemisphere land mass for all seasons, with the exception of JJA. Oceanic correlations exhibit greater variation with the exception of the eastern Pacific equatorial trough, and correlations are noticeably weaker over tropical land masses.

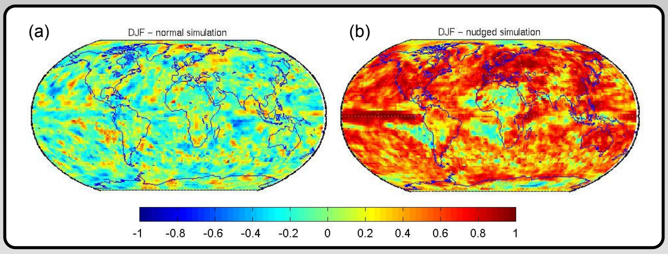


Figure 1 – Correlation of normal (a) and nudged (b) ECHAM5 DJF precipitation with GPCP satellite-gauge observations (1979-2001).

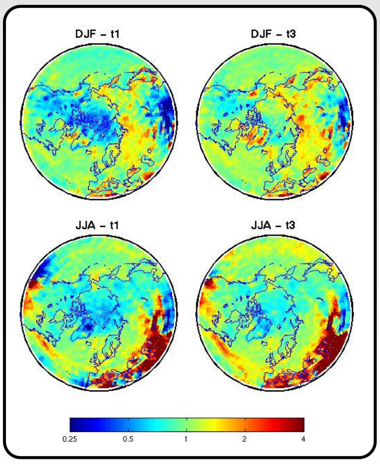


Figure 2 – Bias correction in the Northern hemisphere; a factor of less (greater) than 1 identifies areas where precipitation is over (under)-estimated by ECHAM5.

The skill of ECHAM5 to reproduce observed precipitation amounts was evaluated using bias correction (Widmann *et al*., 2003).

The correction is the factor that would be required to transform simulated precipitation to reflect observations (Figure 2).

Observed seasonal means were split into thirds, the first third (t1; events below the 33rd percentile) consisting of the driest years for a given season.

Scaling factors are close to 1 for the majority of extra-tropical regions. In general, correction factors are less (greater) than 1 for t1 (t3) events suggesting that ECHAM5 is unable to fully reproduce the high and low extremes in seasonal precipitation.

On average, bias corrections for events in t1 are slightly below 1, suggesting that the simulation is overestimating precipitation during these driest years.

4. Potential for downscaling

Precipitation has much greater spatial and temporal variability than other climate variables, and as such, downscaling methodologies are often implemented to produce precipitation estimates on smaller spatial scales. Here, we propose the development of a statistical correction for GCM-simulated precipitation which is analogous to the Model Output Statistics (MOS) approach used in weather forecasting.

A statistical relationship can be derived between the retrospective nudged simulation, in which observed temporal variability is well-captured, and fine-scale rain-gauge observations. It is hoped that a downscaling correction derived between observations and 'realistic' simulated precipitation will be more meaningful when applied to the output of future GCM simulations.

Here, we focus on Europe and calculate a simple scaling factor correction for areas where the correlation is greater than 0.7 i.e. areas where temporal variability is well-represented and subsequent scaling factors can be considered robust (Figure 3).

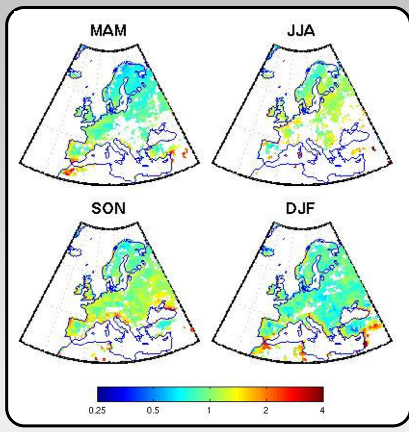


Figure 3 – Scaling factor corrections for Europe, where overall correlation > 0.7 (0.5° x 0.5° GPCC gauge-only data, 1958-2001).

Figure 3 shows that, in general, ECHAM5 precipitation is in good agreement with rain gauge observations between 1958-2001. In many areas, scaling factors are close to 1, suggesting that ECHAM5 precipitation is already a good 'predictor' for regional precipitation without the need for a scaling transformation.

When applied to the nudged ECHAM5 precipitation field, the cross validated correction is skilful in reproducing observations at a number of key locations, such as the Mediterranean Basin (shown in Figure 4).

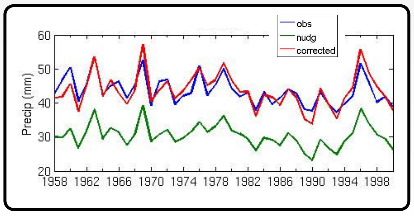


Figure 4 – Observed, nudged and corrected precipitation for Mediterranean Basin (1958-2001).

5. Main conclusions

- An ECHAM5 (T63 resolution) simulation nudged to ERA-40 was shown to capture well the temporal variability seen in observations.
- In quantifying the spatial skill of simulated precipitation from ECHAM5, we have identified areas where temporal variability in observed precipitation is well-captured.
- There is excellent potential for a statistical downscaling correction of ECHAM5 precipitation in a number of key regions; this will be the focus of further research.

Selected references

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